Ecological Design: Reinventing the Future

presented by
John Todd

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Introduction by Starling Childs,
forester and member of the Board of Directors
of the E. F. Schumacher Society

It is a great honor for me to introduce John Todd, someone whose work I've followed for many years. As a forester and fellow applied ecologist I've shared many moments with John, discussing the mysteries and the magic of the forested ecosystems and the wetlands associated with them. As he said to me just recently, those systems have the codes. They have the codes from which he has been able to divine and design his living technologies for restoring degraded waters and land systems. In 1969, together with Nancy, his colleague and wife of many years, John founded and led New Alchemy Institute, the great experiment in alternative technologies and energy in Falmouth on Cape Cod. New Alchemy soon attracted numerous environmental stewards who shared John's zeal for making the human-built environment both more earth friendly and less energy consumptive.

John and Nancy left New Alchemy in 1981 to found Ocean Arks International. The mission of Ocean Arks is to find ecological solutions for the pressing concerns and

problems involving water pollution issues around the world and here at home as well as to restoring degraded ecological systems. Today John is, in his own words, an itinerant biologist dedicated to earth stewardship. A man of modesty, with a good sense of humor, I see him as a leading revolutionary for positive change who has played a major role in bringing about a true paradigm shift in our approach to natural and technological systems.

He is a distinguished lecturer and professor, currently teaching applied ecology at the University of Vermont in Burlington. John's story is soon to appear in Inventing Modern America, *a book from MIT Press that identifies him as one of the twenty most influential agents—and I would say angels—for positive change in America.*

Standing here in the pulpit of this church I can't resist telling you that when I was a Sunday school student, my mother always ended the class with the words, "He's shown you the way, o man, now go forth and do his good work." I can honestly say that John Todd has shown me the way for years, and I've never been led astray in following this man's good work.

Thank you, Starling, and I would like to thank the Schumacher Society for inviting me and also for being all that it is. In times like this we need the Schumacher Society more than ever. And finally I'd like to acknowledge and thank my closest associate, Nancy Jack Todd, the editor of our publication *Annals of Earth. Annals* tells the story of the work you're going to hear about and carries reports by colleagues around the country.

Today I am going to talk about ecological design and what it can do and mean for us. You'll see that what I say is linked to the theme of the lecture Amory Lovins will give this afternoon on natural capitalism. They are part of one cloth.

What is ecological design? It is the intelligence of nature applied to human needs. The natural world for the past three-and-a-half billion years has been inventing, experimenting, evolving, developing associations and relationships among life forms—relationships so powerful that they are almost impossible to appreciate fully. In aggregate, evolution has created all life as we know it and has forged the relationship of all life to the mineral, atmospheric, and aquatic realms that sustain the complete living family inhabiting this earth. So I would argue that ecological design is one way of forming a new partnership between the ecological needs of the planet and humanity.

Where does one go to learn about it? How does one start along this journey? I think Starling alluded to the way: you find a piece of the world, an ecosystem or an ecology, that has meaning for you, and then you delve into that system and begin to learn its narratives, its stories, its relationships, and its architecture. Out of all that you begin

to decode the roadmaps and blueprints for the design of human artifacts and infrastructures. For example, the forest is one of our greatest teachers. If you lie on your back in the forest and, looking up through the trees, contemplate their architectural forms, you will see that they are not only beautiful, they also can have great meaning for designers—if we learn to understand the relevance of the way the forest alots its resources and the way it builds food chains and relationships in its soils. What does it do that we need to know how to do in order to sustain ourselves in the future? That is an interesting story which we need to decode.

How is it that systems sustain diversity and longevity, and how is it that over time these systems are able to deal with perturbations? The answers lie in the story of ecosystems. Fungi, one of the largest species on earth, live beneath us in the forest, scarcely understood, but they do have great meaning for us. One can also go to other environments and learn from them too: for example, coral reefs can tell you how to work in a nutrient-poor, sun-rich world; we can learn from prairies or from mangroves, where the sea and the land come together; from savannas or deserts, where everything seems to be etched so starkly yet there is a full panoply of relationships; or oceanic meadows. All of these places can become our teachers and tell us what to do.

The next stage is to take nature's intelligence and apply it technologically in order to reduce the destructive human footprint on this planet. I argue that it is possible, by using nature's intelligence, to reduce this negative human imprint by 90 percent. So there is reason to be hopeful about the future if we can decode this information soon

enough and then apply it in our daily lives.

Over the past several decades I've been fortunate to have some amazingly able colleagues to work with as we invented and evolved a family of living technologies. These are technologies that take ecological ideas and apply them directly to human needs in the areas of food production, generation of fuels, conversion of wastes, and repairing of environments as well as to architecture, education, and teaching. It is encouraging to see that over the past ten or fifteen years these technologies have begun to spread around the world. For example, we have been working in Brazil, Australia, and the United States on the processing of high-strength food wastes from industries. We have projects for the conversion of industrial wastes into beneficial organic materials in Canada and England, for the transformation of human waste into new products and pure water in Asia, North America, and Europe, and for environmental repair in the United States, China, and central Europe. These ideas are moving out into the world, perhaps not quickly enough, but at least they've started, and I see that as another reason for hope and optimism in these times.

I want to focus on two areas of our current efforts at Ocean Arks International. Ocean Arks is a Vermont based, nonprofit organization founded by Nancy Jack Todd and me about twenty years ago. First I want to talk about what we are doing to repair damaged and polluted waters, as illustrated by Flax Pond on Cape Cod. Flax Pond is connected to the water table of the town of Harwich. Since the early 1980s it has been assaulted by about 30 million gallons a year of toxic waste from a local landfill and septage waste dump. The pond was close to dead: there was

no animal life on the bottom, its oxygen was gone, and its ability to self-maintain and self-heal had been lost. When we set out in 1990 to restore this pond, the first thing we did was to put floating windmills on the surface. The windmills turn blades under the water, and when they spin, they create up-wellings so that the dead bottom water comes to the surface, where it is exposed to light, and then it flows outward as a surface film. Into the adjacent environment we introduced very finely ground rock flour to provide a mineral basis for the transformation of the pond. The remineralization began to create the healing process; however, the poor pond was being hit with too much pollution, so we invented a floating technology called the Restorer.

A Restorer is a device, in this case powered by the sun and wind, that pumps water up to the surface, where it flows through ecologically engineered "chambers." In each chamber is a different type of ecology, which is put there to carry out a specific task. A partnership ensues, not only among microorganisms but among higher plants, snails, clams, and fishes. It is all of these characters working together that create positive change. The ecologies begin to act like what bacteriologists call chemostats. They actually produce large numbers of beneficial organisms, which flow out into the pond. These organisms are so effective that within two years the biological diversity increased fourfold, and over two feet of sediments that had been accumulating on the bottom were digested. To be blunt, the natural digestive metabolism of this pond had been constipated by the pollution, and what this treatment did was uncork it.

As our learning increased, we found ourselves facing

a greater diversity of pollution problems that needed solving. We developed a Restorer for a very large waste lagoon in Berlin, Maryland, into which pour a million-and-a-half gallons a day of high-strength organic waste from a poultry-processing plant that slaughters a million chickens a week. The lagoon was all there was between the processing plant and the Chesapeake Bay watershed. We built a huge floating structure, with the underwater part made of a textile medium that supports communities of aquatic life. It is shaped like kelp, hanging down like an artificial kelp forest so that there is very gentle aeration, which causes upwellings. In special cages on the top of the structure we planted 28,000 higher plants, including trees and shrubs, and added many kinds of animals to create a floating ecology; in concert this diverse life was to remove the high-strength waste and purify the water. Within a few weeks the plants had grown remarkably quickly. Each plant has a different role: some break down certain compounds, some sequester others. What this technology did was allow us to reduce by a factor of five the electrical power required to convert that waste, which was previously a conventionally activated sludge waste-treatment system. We also reduced the capital costs of treatment by about one-half.

Floating ecological complexes have a powerful role to play. We are now beginning to see them as potentially helpful in agriculture as well. They can be built to be sufficiently cost effective for farm use, whereas most conventional treatment is so expensive that it would put the farmer out of business. Here is an opportunity to change the equation. There is another way to change the equation: if commercial products, both plants and fish, are introduced

into these systems, it's possible to combine on-farm waste conversion with a new form of food production called aquaculture and actually turn an expense into an economically viable enterprise.

We have just made an agreement with the city of Fuzhou in China's Fuijan Province to build Restorers there. The city, with a population of 1.4 million, has roughly 50 miles of canals, which directly receive the waste from approximately 900,000 people, with the result that raw sewage is floating throughout the city. We have taken on a huge job. We are doing it as a joint venture with a Chinese/Canadian group. We are excited about it because our hope is that with Restorers on the surface, fish will be able to survive in the canals, breeding and growing and helping to clean the water to the extent that the fish themselves will be healthy enough to eat. As a recreational and aesthetic feature there will be walkways along the canals. Biological productivity on the Restorers will also include medicinal herbs, integral to Chinese medicine. We are undertaking experiments with herbs and endangered plant species in a project in Hawaii right now.

I have told you about the repair of damaged and polluted waters. Now I want to turn to the second area of our involvement, which is the heart of my talk—namely, natural capitalism at work. Ocean Arks is part of a team creating an eco-industrial park in Burlington, Vermont, with an agricultural theme. An eco-industrial park is a concept I think you're going to be hearing more about in the next few years. It consists of enterprises that share their resources so that the waste or excess of one enterprise will be an in-put component of another. The idea is to create a

working ecology, an ecology of enterprises that provide synergies amongst themselves, reduce their costs, and share knowledge, such as legal and other skills. In addition to the development of human resources there is a strategy of moving toward zero emission of wastes. What you end up with, if it's done right, are economic gains together with great improvements in environmental quality. Our work on the eco-industrial park is an example of ecological design.

There is a section in downtown Burlington called the Intervale, 700 acres of bottom land right in the city, and it has become an amazing incubator of new farms. The Intervale Foundation, which manages it, provides beginning farmers with land, tools, and mentoring so that they can develop the necessary skills without having to come up with the capital costs that choke most agricultural innovation and start-ups. The only thing asked of these young farmers is that when they get good at what they do, they in turn will become mentors, contributing to a pyramid scheme for creating good. You could call it a hotbed of innovation in terms of the ecological management of livestock as well as crop production. Experimentation is going on with grape varieties and small fruits, and seed trials are being conducted. Shep Ogden of Cook's Garden Seeds is constantly evaluating new crop varieties. The place is infused with the great vision of Will Raap, who is president of Garden Supply. The Intervale has the support of the city, which composts most of its organic resources in a viable facility there. This is a yeasty place and a hive of activity, so it's not surprising that people would begin to talk and think about an ecological industrial park with an agricultural focus for this attractive area.

One of the key components is a fuel-generating plant that produces electricity by burning wood chips from the forest industry. It is the largest wood-chip plant in the country. Its operation requires cooling towers, which emit large amounts of steam, producing a dust-filled local climate that makes the neighbors angry. All the clouds coming from the cooling towers also reduce the sunlight in the area. The initial step for the ecopark is therefore to eliminate the use of the cooling towers. Instead, the hot water will go to underground radiant heating for buildings, including greenhouses. In other words, the catalyst here is the productive use of all the waste heat. The park's commitment to use the heat makes the economics of the power-generating plant much more favorable, and that is an important step.

The major players in this enterprise are the city of Burlington, which provided the seed funding, and the Intervale Foundation, which is the developer. When we began to put this ecopark together, there were businesses of two types that we looked at. The first, which any developer likes, is businesses that are banging on the door saying they want in, and they scarcely ask what the rent is. Included here are a composting enterprise, which wanted to diversify its products; a local brewer, who wanted to make organic beers (the Intervale is all organic); a fish-farming group, of which I'm a part; and a group of people who wanted to grow foods for the city year-round. The amount of food being produced locally in Burlington is creeping toward 4 to 5 percent. The city would like to bring that figure to 10 percent or more, so there are critical food security issues involved here as well.

There is a second group of businesses that we considered. Professor Karel Sampson from Nyrenrode University, Holland's premiere business school, sent seven of his top students to evaluate businesses for suitability in an ecopark designed specifically for Burlington—ecoparks are all going to have to be place based. By talking to potential entrepreneurs and doing a preliminary analysis of the business potential, they found six businesses that would be suitable for the ecopark. The first was a greenhouse business, and we know there is a demand for greenhouse space; the second was a florist (which showed a good return on the investment even though flowers for cutting are trickier to raise in an organic environment); the third a bakery; the fourth that was viable on the basis of their analysis was a restaurant; and the fifth, marginal but still viable, was gourmet organic popcorn, which did look as though it would attract investor money. The sixth business was mushrooms, which promised to be especially viable, in part because of all the available organic material, but before the business students could sign off on that one, they said some research and development would have to be done. We decided to go ahead with the research and development ourselves, and I'll tell you about that in a moment.

There were three businesses that failed the test. The first one was potato chips, even organic potato chips. Apparently the industry is controlled by two or three giants, and it's very hard to establish a niche. The second was the manufacture of biological plastics for wrapping and packaging, the kind that will degrade. Without the waste from potato processing, the plastic enterprise wouldn't

work either, because it had little feedstock. The third business, biodiesel, also failed in this context. Now, what the business students were very clear about is that the three which failed in Burlington might succeed in any number of other places. The eco-industrial park concept is very definitely a place-specific enterprise, a concept that I think would have pleased Fritz Schumacher.

The first Intervale project I want to tell you about is a fish-farming operation housed in a greenhouse with sixteen plastic tanks connected in four clusters of four tanks each. (See centerfold diagrams.) Within each cluster the water circulates between the tanks. Our inspiration for the design of this system was eelgrass communities, found in shallow marine waters. We asked of them, What do you know? How is it that you are one of the most productive places on earth? How do you do it? And then, inside those tanks we try to do what they do and develop a fresh-water analog of an eelgrass community. In the first tank we have nothing but fish— golden tilapia and blue tilapia—doing what fish do: they feed and they make waste. The fish are fed algae grown on screens downstream from the fish.

In the second tank we have created a freshwater plant community designed as an analog of an eelgrass community in the ocean. What eelgrass communities do is slow down the movement of water, build up sediments, and produce the foundation of food chains. In our system we have added clams, snails, worms, and other kinds of burrowing animals. We have an artificial medium for attached communities as well, and we have a number of aquatic plant species that are critical to it. The system produces its own oxygen, using sunlight as the driving

force for photosynthesis. The aquatic community in this tank takes wastes, which are normally a problem in aquaculture, and converts them into sediments as part of the growth cycle. The artificial medium is a substrate to which oxygen-producing algae and plants attach. As a result we are not using chemicals or large amounts of energy and electricity in an attempt to convert ammonia into nitrates and then off-gas the nitrogen into the atmosphere. What we're trying to do is make rich bottom sediments. We don't have to worry about what's going on inside this second tank because the fish are not in it. They are in a healthy pond upstream in the cycle.

The process continues in the third tank, but here we do not accumulate sediments. At this point in the cycle we want to make sure that the water quality is becoming pure enough for fish. By this stage we grow horticultural crops on floats on the surface of the water; the water then flows to the fourth tank, which is made up of higher aquatic plants growing on the bottom and screens that grow attached algae. If one lifts out the screens and looks at them under a microscope or a hand lens, one can see that they are crawling with animals and plankton as well as over a dozen species of green and blue-green algae. And all of this community derives its energy and nutrients from fish wastes and sunshine! This ecological approach allows one to do away with the chemicals used in conventional aquaculture because the fish farm "knows" what an eelgrass community "knows."

In one experiment we allowed the fish to grow by feeding only on organisms cultured within the system itself. The conversion efficiency in this trial was extraordi-

nary. Without external feeds, however, the fish grew more slowly than we wanted them to. When we supplemented their diet of internal foods with a small amount of professionally formulated feed, we maintained a respectable feed conversion efficiency while obtaining fish growth that is necessary for commercial viability. At present the fish are being sold through a Community Supported Agriculture program, but we have yet to reach a commercial scale. In the system I have described we tap off the strongest, richest water from the tank that houses the fish and pipe it into aquaponic grow tanks, where we culture basil and watercress; with basil as a winter crop, this is an important economic feature. Our financial return for basil on a square-foot basis was very good.

On the other side of Burlington is the Magic Hat Brewery, and across the railway tracks is a greenhouse we operate, a pretty place filled with beautiful flowers and plants. There are over 400 species of plants being cultivated and evaluated for their use in waste treatment, but the facility smells like a tropical garden; one would never think it's a sewage-treatment plant. For four years the system treated 80,000 gallons a day of sewage from the city of South Burlington. Now it is being converted to treat brewery wastes, both the liquid and the spent grain portions. Plants growing in special racks on the surface of the water in huge tanks provide us with water purification and filtration. After these plants have completed their duty as water purifiers, we divide them and place them into pots. They are then sold into the horticultural trade. Each plant has a little sign that says, "Besides enjoying this plant and having it purify the air in your house, you have helped us

clean up water." Any time you are in South Burlington, come and buy our plants.

In the springtime and early summer there are aquatic plants available for people to buy for their water gardens. We are trying to demonstrate at the South Burlington facility that waste conversion can be an economic engine, not a burden on society. What we do is cascade wastes into new products. Bait fish and ornamental fish are grown on the bacteria that are the natural byproducts of converting waste. Our facility provides winter fisherman with bait fish, the golden shiners and fat-head minnows they need for ice fishing, which is very popular in our part of the country. The summer crop is koi and goldfish, which are suitable for the aquarium trade. What the fish do in the system is remove some of the sludge that would ordinarily have to be incinerated or put in a landfill.

One of the brewery wastes is spent grain, and breweries make a lot of it. Our research is directed toward adding value to wastes. Inside our facility is a special chamber in which step one of adding value to the waste takes place. The brewery waste is blended with dry rye straw and then pasteurized and bagged. Mushroom spawn is inoculated into the bags, which then go into a special dark chamber where the mycelia grow and, under ideal culture conditions, fill the bag space. The mushrooms are transferred into a sky-lit room. The result is a crop of beautiful and tasty oyster mushrooms. Right now we can't grow them fast enough. Our goal is to convert every pound of spent grain and straw into a medium that produces one pound of gourmet mushrooms. The Dutch business students calculated that as little as a thousand square feet of mushroom

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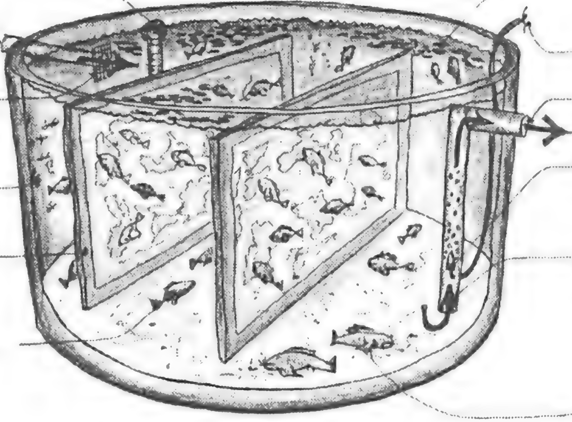

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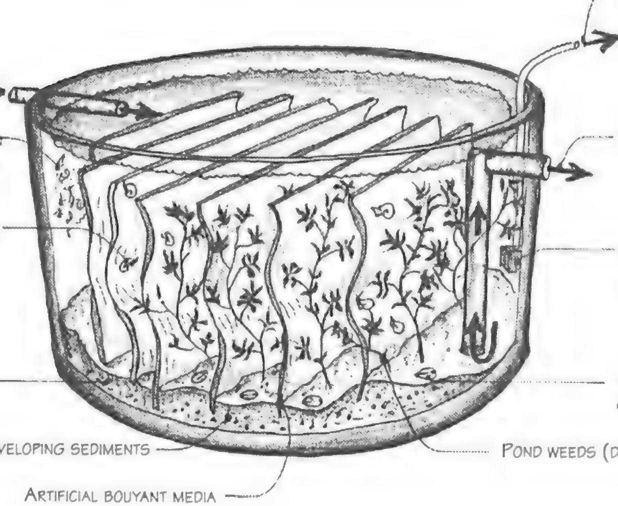

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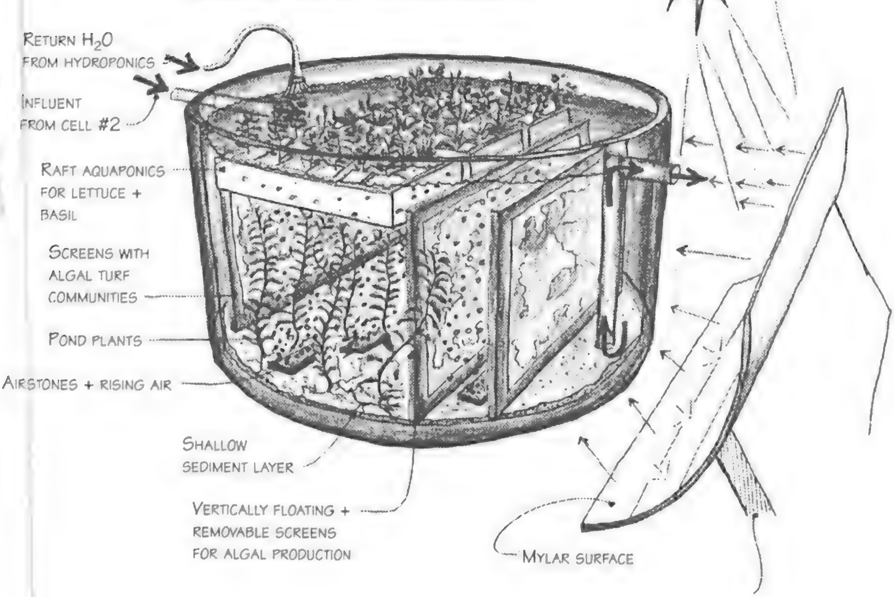

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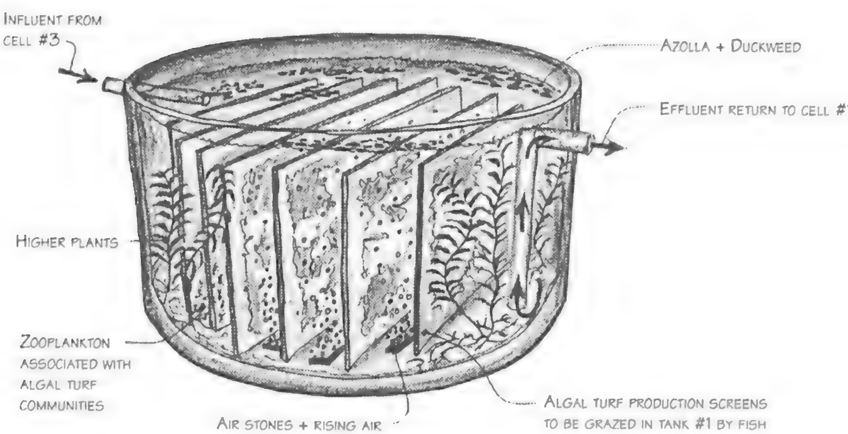

chambers could produce a small micro-enterprise with a reasonable return on investment. On that scale, selling organic mushrooms directly to consumers could provide a viable secondary business for a family.

After the mushrooms are harvested, the growing material is still filled with all that mycelia and has increased in value. It is good stuff, containing enzymes and amino acids, which can be used as high-quality livestock feed. We are currently testing it on both fish and chickens. But this is not the end of the story. The post mushroom medium then goes into special bins for the culture of earthworms. The product that comes out of the earthworm cultivation—in addition to earthworms, some of which are blended into fish feed—is wonderful soil with worm castings produced by the earthworms in the relatively short period of one month.

The final stage in adding value to the original brewery waste involves the growing of leafy green crops. The earthworm soil is laid out into shallow beds only about six inches deep, where mixed greens, including mesclun, are grown intensively. This sequence is a very practical example of ecological design, resource sharing, and nutrient amplification.

We are still putting together the pieces of the ecological jigsaw puzzle of the agricultural ecopark; we're not all the way there yet. Ocean Arks needs philanthropic financial help to complete our analysis of the subcomponents and to develop real-world business plans. And the ecopark itself needs further investment to match the city's contributions. The city of Burlington is building all the infrastructure, including the heated slabs that the buildings will go

on. The story is developing quickly, and construction will start in the spring of 2002.

What is fascinating about all this is that as we develop these ecologic enterprises, I begin to see a model for village and urban food production that includes ways to employ more people who are creating more of the things that help sustain our health in beneficial kinds of environments. Mushrooms are one example, with different kinds used as medicines or as food, and organic fishes are another. In what I consider to be very troubled and unpredictable times we have the means to strengthen our food security. This is something that Europeans would understand almost at the blink of an eye. In North America we seem to have trouble imagining what food security means.

I am delighted that some of my students were zany enough to get up in the middle of the night and drive down here to listen to me talk—it's quite a compliment. The reason I mention this is because together with them we are creating a new culture based on earth stewardship, and I'm proud to be a part of this collaboration. That is the most important aspect of what I have been talking about today. If Fritz Schumacher were here, after hearing the three speakers, I think he would say, "What I set in motion is going to work." I think he would be optimistic about the future.

Excerpts from the Question & Answer Period

Would you please comment on Monsanto purchasing almost every seed company in the United States and genetically altering our seed source?

As an ecologist I'm deeply worried about the impact genetic altering will have on natural ecosystems in the long run. For example, the canola field of a farmer in Canada was contaminated by pollen that blew onto his field from a neighboring crop of canola grown from genetically altered Monsanto seeds. You might expect the farmer to have sued Monsanto, but in this case Monsanto sued the farmer for misappropriating its patented property! The farmer, who obviously had right on his side, lost the lawsuit, but legal victory has nothing to do with right; it has to do with muscle, and he didn't stand a chance. There are other similar examples.

I'm also extremely unhappy with the kind of financial relationships that have developed between corporations and farmers. And I am unhappy with the private ownership of nature. First we cordoned off the lands and now the life forms. I think that is a spiritual failure,

In a book of interviews called Eco-Pioneers *by Steve Lerner you were interviewed about work you were doing for a candy factory in Texas. How is that progressing?*

We've done a couple of candy factories. The one I would particularly recommend that you visit is Ethyl M. Chocolates in Las Vegas. In the middle of a desert is a wonderful garden, beautiful as can be, which is part of a system that takes the factory's waste and converts it into

water so pure that instead of being discharged it is re-used. This is a zero-discharge facility, not for producing chocolates but for other things they do on the site, including maintain their desert garden.

The other one is a Snickers Bar plant in Waco, Texas. If you walked around it, you would think you were in a beautiful garden. It's all curvilinear; the tech part is completely hidden. You see water flowing here and some fish swimming there, and you have no idea that they are hard at work on waste that is very difficult to treat. Chocolate waste is what they call in the business FOGs—fats, oils, and grease. Most technologies don't like fats, oils, and grease.

The number of lakes in New England that are suffering from severe eutrophication is probably increasing. Could you describe how many of them are being treated by your floating community Restorers and what kind of luck you're having?

The towns of Weymouth and Harwich in Massachusetts each have one, and former President George Bush has one in Kennebunkport, Maine. There are a couple in Hawaii, one under construction right now.

There are not many, and the reason is that most communities, when they want to give this method a try, will contact the town engineer, and the town engineer contacts a consulting firm, and the consulting firm says, "What you need is a little alum to get rid of the phosphorus in this pond, and after that treat it with a little copper to get rid of the algae." The town does that, but after a few years the algae come back. We would like to step in, but the difficulty is

that communities have to struggle for a year or two or three or four before they can eventually raise the $50,000 to $100,000 that it's going to cost to do it our way. By then the poor person like me, who's negotiating with the client, is broke.

I know that many people have composting toilets and a sort of constructed wetlands for gray water. What size community or what amount of waste would make one of your living systems economically viable?

Basically, the natural systems technologies are on a spectrum from a constructed wetland in a place where there's a lot of land to a living machine inside a building in the middle of a city. The living machine fits best inside a building because space is at a premium. The constructed wetlands fit best in a village that may have a commons or land around it because it's less expensive per gallon to produce. And then there are all sorts of technologies in-between, including those with a little bit of wetland and some Restorers on a deep lagoon. They are effective for most communities. Other communities should have nothing but composting toilets and gray-water treatment. The situation is so place specific that there's not a single answer, but what *is* universal to all of them is respect for the complex natural systems that can be put in place and do the job .

Were you using municipal sewage in your installation for fish in South Burlington?

Yes, we were using municipal sewage until the beginning of the year 2000, but now we're converting the facility

to treat nonhuman contaminated waste from the Magic Hat Brewery. We have to re-do some piping, and we're working with the brewery's spent-grain solids as well. We're about $35,000 short of being able to complete the conversion. Incidentally, by coming in with us the brewery can reduce its discharge costs because those costs are determined by the strength of the waste times the volume. So it's to their advantage to have us in this with them.

According to the Organic Food Act, municipal waste should not be used for growing food.

We would not use human sewage for that purpose. Even if we sterilized it with ultraviolet light, we wouldn't do it because of the cultural barrier. The reason why we stopped treating sewage is because South Burlington had a brand new plant in the works long before we got there, and it is now in operation, so they don't need us the way they did a little while ago. Secondly, the reason why that plant was put there in the first place was because the Environmental Protection Agency—it was EPA funded—was concerned about whether the ecological treatment would work with the cold water in winter, which is a valid concern. We proved that nature works in the north too.

You're not using municipal waste for food production, but do you see it as viable in spite of heavy metals or other substances that are difficult to treat in waste? Or would you recommend it be filtered out?

When we want to remove materials such as heavy metals that are difficult to treat, we try to do that upstream. Because of the electrical charge between the cells of the

plants and the metals, the best way to remove metals is on attached algae communities. They will strip out heavy metals in the first eight hours, and you simply remove the screens with the concentrated metals. Then you can recover the metals by means of an acid bath. There are a few wastes that have enough metals to recycle, but even though it's technically possible to sequester and recycle them, the economics in most instances I've looked at are dubious.

You alluded to the domino effect in an industrial ecopark. If a crucial company fails for one reason or another, then the whole thing falls apart. How do you guard against that?

First the developer has to look very carefully at the viability of the businesses that are going in. Even with that, some are still going to fail, so there are two precautions: one is to develop redundancy. For example, we'll talk to two brewers, not one, or have a second one in the wings; we'll have two growers, not one. The other thing that helps ultimately is the diversity of the enterprises. If you have ten different kinds of enterprise, you can lose one or two; if you have three kinds of enterprises and you lose one, the whole thing could be destabilized. The power of the ecopark idea lies in diversity of enterprises. I think that's the only long-term safety net.

There are eight or nine industrial ecoparks around the world, the most famous one in Denmark. I think the diversity there is six or seven different enterprises. These ecoparks can be made into places where the public wants to be, and they can be exciting architecturally. I'm hoping there will be a whole generation of architects who say:

"Okay, Gossamer Engineering, let's do it. Let's move beyond the rectangular greenhouse and build the marvelous structures that are now technically possible."

Do you think that living systems can treat substances such as PCBs?

I have worked with a large number of the toxic organic chemicals, petroleum derivatives, coal-tar derivatives, all of which are dangerous. I've worked with DDT and been able to snip all of these compounds apart ecologically. I have never worked with PCBs directly, and I've never worked with dioxin directly, but there is no theoretical reason why they cannot be broken down as well. To do the job, I think it will take ecological elements that are terrestrial and fungally dominated, linked to ecological systems that are aquatic and microbally dominated, with algae in the mix. In other words, I believe that this level of ecological complexity, with the exchange of the waste back and forth between those two systems, will break them down. My guess is that it would probably take as long as thirty days, but the mycologist Paul Stamets thinks they might be broken down in even less time than that, maybe fifteen to twenty days.

With safe drinking water such a valuable commodity for less developed countries, do you see ecological technologies as having the potential to deal with viral diseases and vectors so that natural water systems can be purified for community consumption?

Amory Lovins brought me into a project that is studying the feasibility of making refugee camps sustainable.

There are millions of people around the world who are homeless, and one of our responses to their plight was the idea of the transparent tube—a pipeline, only it's clear; you can extrude clear pipeline material that goes for miles. You seed the inside with all different kinds of aquatic life, which can't come in contact with the atmosphere. During the day the sun shines on it, and gases are formed inside so that the tube swells up like a balloon; then at night the darkness of the CO_2 world is dominant, and the oxygen begins to disappear, with day-night pulsings as a result. The water flowing through is filled with various kinds of viruses and pathogens, which are subjected to great ecological diversity in the pipeline and great oscillation in the environment. We believe in theory that it is possible to eliminate most diseases in water effectively, ecologically, and cheaply. What we don't know yet and hope to learn in the next year is the length of time the material would have to be flowing through pipeline exposed to sunlight. Without sunlight the whole thing won't work. That's one of the ideas we're looking at for treating human pathogens.

I was delighted to discover that you are included in the book Design Outlaws on the Ecological Frontier, *and I do see you as somebody who's way out at the edge, at the fringes. I appreciate that, and I'd like to give you four brief examples of directions in which I think we should be heading but that seem as though they're still on the fringe. The first example is that we have been trained all our lives to think of ourselves as indoor creatures who occasionally go outdoors, and this radically affects the structures we create for ourselves. I'd like to think of myself as an*

outdoor creature who occasionally goes indoors. Is anybody thinking along those lines?

The answer is yes. That is key to the emergence of a partnership between nature and culture. Most of us, including me, will spend too much time in front of a computer screen if we're not careful, and we need to avoid that. One way to avoid it is to create the kinds of architecture that the New Alchemists did on Prince Edward Island and Amory Lovins did at Rocky Mountain Institute, where the indoors and the outdoors are separated by just a series of membranes, and you're interacting with both all the time.

My second example: I understand that there are cultures in which the concept or the word "waste" does not exist. I think it must radically shift one's thinking to assume there is no waste or to see it in a different way.

There are cultures that don't acknowledge the concept of waste, and they are indeed viable. Right now we're in an awkward position in that we have created new chemicals we have to pay attention to and consider as waste because they are not natural compounds and may have pernicious effects. We have to know what substances are floating around, whether they're endocrine disrupters or something else, and watch out for them. I would argue that our level of purifying drinking water is not good enough yet, and I'm partly to blame. I've never developed a living technology to ultrapurify drinking water out of the tap. I feel bad about that.

The third applies to me personally: I had a stroke, and because of that I pay a lot of attention to shut-down sensitivities. I have come to feel that our culture is shut down in different ways—around right brain/left brain, to

mention just one. Is any attention being paid to the ways we have become comatose or walk around in a daze? What will make us become aware of it? Einstein said you can't solve a problem out of the mindset that created it. Are there people struggling with those kinds of issues?

There is a whole new field called ecological psychology, and there are a number of people in this room who are involved in it. It's a wonderful time intellectually. Nancy Jack Todd's lead article for the next issue of *Annals of Earth* explores the idea of creating an alternative to the current psychology that came out of the September 11 attacks on the World Trade Center and the Pentagon. The Worldwatch Institute, for instance, has proposed the equivalent of a Marshall Plan for the world. Some interesting, creative ideas are emerging that are much needed for the soul of the culture as a whole.

When you talked about a million chickens being slaughtered every week, I was concerned about the scale of that.

My concern in that situation is saving the ocean. I'm worried about the ocean, and I'm trying to conduct a rescue operation on its behalf by putting our system in place between the chickens and the ocean. I am not attempting to critique the industry in this case.

Our group in the Intervale raises chicken-tractor-based poultry, and I just love going behind the chicken tractors, watching them scratch away and clean out the weeds. They're doing all the work.

Have you thought about alternatives to using plastic tanks in what you design?

In most cases we work with completely recyclable plastics. But like all of us in this room we occasionally sin and use PCB piping, although this is increasingly less the case. The alternative to plastic tanks is an in-ground basin, like a pond, and floating on that pond is a Restorer to maintain its health.

What is your view of genetically modified organisms?
The biotech industry is looking for magic bullets. They want simple solutions to complex problems because that's the way to make a lot of money. Nature doesn't work that way. Nature is a symphony, with all different kinds of instruments making different sounds, and collectively it produces a sort of celestial music. That's the way we should be working with ecologies—as symphonic forms—but these are harder to patent, thank God. They are also harder to explain, and they're harder to get rich from. But they work beautifully, and they will go a long way toward sustaining us.

Are you doing anything in the way of providing teaching aids?
We have miniaturized living technologies that fit on a table top, available from the National Gardening Association and from Carolina Biological Supply. Kits are sold with a companion book and some web support. Teachers use these living machines as a highly visible means to introduce children of all ages to how nature works. There are already eight or nine of these systems in use in the Burlington area and probably three hundred in schools throughout the country.

In fact we are very active in the development of educational tools and have a small but dedicated group committed to it. You can learn about this on our website, which is www.oceanarks.org.

I remember visiting New Alchemy Institute in the 1970s when you were excited about finding a use for tilapia. A couple of years ago I was in Bangladesh to learn about the Grameen Bank, and I was way out in the middle of nowhere. I was taken to a woman who was living on the streets, but she had a plot of land, and she took me to it and showed me what she had done with it: there were banana trees and chickens and a little pond. When I asked her why the pond, she said, "Todd here! Todd here!" I feel great appreciation for you and your team at New Alchemy and what you've created

Bill McLarney, a co-founder of New Alchemy, actually gets the credit for that. He's the one who asked, Can we find a fish that's low on the food chain, is really tasty, doesn't have any diseases, and breeds easily? What he came up with was tilapia. There were no tilapia in the United States at the time, and then Professor Shell at Auburn University brought some in. We were able to get his brood stock in 1971. Now I think tilapia is the fastest growing cultured fish in North America, thanks to people like John Reed in Massachusetts.

Tilapia are so popular because they can be raised in the backyard by tropical people; they can be raised in rain barrels, although in the Far East people prefer another species for raising in rainbarrels, one of the anabantid fishes, which have lungs as well as gills. In the dark

monsoon season when the water loses oxygen, they survive by gulping air to get oxygen.

We need to divert the money the government is now spending to destroy the earth back to healing the earth. Would you care to select the priorities?

Obviously I am deeply concerned about water. I am deeply concerned about revegetation of the planet. If you look at photographs of the trouble spots of the world, you'll see that the land is almost naked. Thirdly, I'd like to find ways of being able to travel without polluting, because we can't stop traveling. One of the reasons we started Ocean Arks was to create a hybrid ship that would allow people to travel around the world without causing all those smoke clouds that steamers make, and one of the reasons Amory is working on the hypercar is that it will be much less harmful to the atmosphere. So I would choose water, revegetation, and transportation. A final priority is a social one—the equity issue. Nothing good can come from the inequities all over the world today.

At the local level there are a number of landowners and organic farmers here in the northeast who I think would be interested in adopting aspects of your technology. Can we contact you or your people to help us with new ways to think about our ponds, our manure stocks, our markets?

Yes. We can help people connect our methods to place-specific situations. We're dealing with knowledge that is universal, but its application is place dependent, and every place is different. One of the best ways to transfer that

knowledge is the old-fashioned way: come visit and talk and kick tires, and then you may want to invite one of us to look at your situation. The knowledge spreads that way. I believe person-to-person conversation can trigger change.

Do we need to make an appointment? How do we reach you? How do you handle it?

If you're going to the South Burlington facility, you need to call to make sure somebody is there. As for the Intervale, it's best to go sometime from May through October because it still doesn't have that year-round liveliness it will have two years from now.

Call (802) 860-0011. The greenhouse is (802) 660-8094. If you become a member of Ocean Arks, International, and subscribe to *Annals of Earth*, we'll keep you informed about what's happening—short courses, things like that. We're probably going to have a web-based newsletter that will keep you up to date with current events.

Closing Remarks

One of the things that struck me at the meetings Amory organized concerning refugee camps and their impact on the host peoples and on the land is how much we as designers have failed the human family by not creating working ecologies. You see the repercussions more starkly and more terrifyingly in those camps.

I was talking about this with my students just this week, telling them how humbled and inadequate I felt in view of the magnitude of the design challenges we are facing. There are 55 in the class, and I presented this question to them: As ecological designers what would *you* do? and I told them to e-mail me their advice. Their responses made it clear that good design is a collective process; it's not an individual genius pushing something onto the world. The best designer in the world can't accomplish alone what 25 people working as a design team can. It takes wisdom rather than a specific expertise to create good design; an ecological way of insuring that wisdom is built in is to have the right number of people working together.

The point I want to end with is that we must not be satisfied with cosmetic solutions to our deep problems. They are too structural and too fundamental for that. I was thinking this afternoon that as a next step in finding solutions we might all go back and re-read *Small Is Beautiful.*

John Todd is an internationally recognized biologist and author of over two hundred technical and popular articles on biology and planetary stewardship. Currently a professor at the University of Vermont, he is a leader in the field of ecological design and has received numerous awards for his work, most recently the Lindbergh Award in 1998. Dr. Todd was cofounder, with Nancy Jack Todd, of New Alchemy Institute, renowned for its pioneering work in the fields of appropriate technology and alternative energy sources. In 1980 the pair founded Ocearn Arks International, a non-profit organization devoted to the promotion of ecological design and engineering. He is also the creator of the Living Machine™, a revolutionary natural wastewater treatment system that accelerates the natural water purification process and has been adapted for use across the globe.

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